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AUTOMOBILES

...BY...

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THIS IS TO CERTIFY THAT THE THESIS PREPARED UNDER MY SUPERVISION BY

FRANK STANLEY HADFIELD

ENTITLED AUTOMOBILES

IS APPROVED BY ME AS FULFILLING THIS PART OF THE REQUIREMENTS FOR THE DEGREE

OF Bachelor of Science in Mechanical Engineering

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A U T O M O B I L E S .

INTRODUCTION.

In writing a thesis on such a broad subject as automobiles it is impossible to cover all the ground available and it has therefore been thought best to limit the subject somewhat. A glance at the outline, which follows will give a general idea as to the scope of the article.

The great preponderance of gasoline motor machines makes that type the most interesting one, and for that reason the details of construction given under division 6 have been confined to that machine, although the discussion of most of the sub-items which do not refer directly to the motive power can be applied to steam and electrically driven machines.

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2. PRESENT STATUS OF INDUSTRY.
3. GENERAL DISCUSSION AND CLASSIFICATION OF MACHINES.
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    - b. Use.
    - c. Weight per $1.00 cost.
    - d. Weight per horse power.
4. DETAILS OF CONSTRUCTION.
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        - b. Shape.
    - B. Springs.
        - a. Form and material.
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HISTORY AND DEVELOPMENT.

The automobile which is now developing with such rapidity is not, at least so far as the employment of the steam engine is concerned, so novel a vehicle as many people believe. It already has a long history which deserves to be epitomized because in it are seen successively revealed most of the parts whose combination constitutes the modern steam carriage.

The first historical record of the automobile occurs in a patent granted in 1619 to Ramsey and Wildgoose which had as a part of its subject "drawing carts without horses". Before this, however, spring power had been tried in Germany and wind driven vehicles in the Netherlands.

By letters patent dated October 10, 1644, Louis X1V granted to "Jean Theson the privilege of employing a little four wheel carriage set in motion without any horses but merely by two men seated", and the Royal Almanack of the period states that in the year 1748 Vancauson in the presence of Louis XV drove "a carriage with clock work springs", respecting which, however, no details are given. It is, however, another Frenchman, Nicholas Joseph Augnot, who should be regarded as the inventor of automobile locomotion. In 1769, he constructed, with state funds placed at his disposal by the Duede Choiseul, the first steam trolley which was, the next year, followed by another somewhat further developed. A model of this machine, belonging to the Conservatoire des Arts et Metiers, was exhibited at the Tuileries in June 1889. It was in reality a

tricycle, the front single wheel being driven by a pair of cylinders acting upon a crank shaft and geared by ratchets to the wheel shaft. The boiler and engine overhung the forward wheel which was also the steering wheel. This, the first actual horseless vehicle attained a speed of two and one fourth miles per hour and was considered, in military circles, a wonderful machine until it began running into fences and walls and became unmanageable generally.

The first American to patent an automobile was Nathaniel Read of Massachusetts, who, in 1790, patented a steam carriage with two cylinders whose pistons were connected to racks which moved pinions on the driving axles, ratchets preventing motion in any but one way. In Read's carriage the exhaust jets were turned rearwards, thus acting as additional propellors. Read's boiler, like those of many who followed him, bore no relation to the capacity of the cylinders except that of equality in the steam space dimensions.

In 1786, William Symington, an Englishman, patented a steam road carriage with a cylindrical boiler supplying steam to the cylinder of an atmospheric condensing engine, whose piston rod communicated motion by means of a rack and ratchet wheel.

Considerable advance in this line was made by Richard Trevithick who patented a steam carriage in 1802; gearing connected the crank shaft with the driving wheels and a fly-wheel was placed on the former. This carriage made several journeys the speed being as high as ten miles per

hour. This was the first automobile in which the power was transmitted by gearing.

The first steam carriage having confortable accomodation for passengers was designed by Joseph Griffith and built in 1821. The boiler had superimposed rows of horizontal tubes in which the water was vaporized and superheated. It is the oldest specimen of the water tubular boiler now so widely known. After acting in the two vertical engines which worked the driving axle, the steam was condensed in a set of thin tubes in contact with the air and returned to the boiler. Considering the date, the arrangement was very remarkable viewed theoretically, but practically it was defective. The water tubes in the boiler were two feet long and one and one half inches in diameter and were flanged to flat vertical water chambers which were connected across the top by transverse and longitudinal tubes forming the steam receivers and, to some extent, superheaters. The cross tubes in the boiler numbered 114, and their heating surface was about 89 square feet, the total heating surface including that of the water chambers being about 115 square feet. Boiler and motor were placed on springs on a rear platform, and the vehicle body, resembling that of a stage coach, rested on springs on two shafts supported by the axles. The rear axle carried the driving wheels to which a number of gears, each giving one rate of speed, transmitted motion from the two steam pistons. The front axle was for steering as in an ordinary carriage.

During the first quarter of the nineteenth century, the fallacy was generally entertained that the adhesion of ordinary wheels was insufficient for traction purposes, and many arrangements were suggested for substituting in their place a system of propulsion by mechanical legs and feet in rough imitation of animal action. Naturally, these push-foot schemes were found impracticable, but the carriage on this system patented in 1824 by David Gordon received much attention.

Walter Hancock, an Englishman was probably the inventor of the first practical steam carriage. He devoted a great deal of attention to this work and made in all nine different steam carriages. His first work was to invent a suitable boiler, and, after considerable experimenting, he patented a very efficient one made on the order of the present day steam radiators for direct heating.

His first carriage made in 1828 was, like most of those that had been made before, a tricycle, the single front wheel being driven by a two cylinder engine. The carriage, however, was very clumsy to handle and had a very small seating capacity, so that he soon discarded it and made another which he called the "Infant". This vehicle was a great advance as it provided more seating accommodation, gave better steerage control, and inaugurated independent chains and gearing. The greatest difficulty was to keep the machinery free from dust and dirt. To overcome this difficulty, Hancock built a larger carriage

with a vertical engine placed in a space near the center of the coach. It was chain driven like the one before it. Seven other carriages were built by Hancock but with very little improvment in the machinery. Some of them were large and were used for commercial purposes but railroad competition soon took away all incentive to this work.

When Hancock started to experiment in this line, the railroad locomotive had not been perfected, and of course the motor vehicle being on improvement over horse traction, had a very bright outlook. The rapid strides, however, taken in the perfecting of locomotives and the ease with which they were able to draw loads on rails, drew all attention to that line, and the automobile was practically forgotten.

From the time Hancock began working on his vehicles until about 1840, there were a number of carriages built, most of them with water tube boilers and a direct drive without a fly-wheel. On account of the adverse laws and public opinion, however, steam automobiles were discouraged to such an extent that all invention along this line, especially in England, practically ceased and the existing machines were destroyed.

From 1850 to 1884 there were a few spasmodic attempts to make a successful steam carriage, but most of the results were clumsy, inpracticable affairs with a large vertical boiler that took up most of the room and made the carriage lookmore like a modern fire engine that an auto-

mobile. In fact, progress in the automobile line hardly advanced at all until 1885.

It was then that the first great stride towards a practical automobile was made by the Frenchman Gottlieb Daimler, when he invented his single cylinder, enclosed crank, internal combustion engine. This was a very practical high speed gas engine with the cylinder diameter small in proportion to the stroke and a hot tube ignition system. The inlet and exhaust valves were close together, one immediately above the other, the inlet being automatic, and the exhaust actuated by a rod worked by a double cam groove in the outer face of one of the enclosed fly-wheels. The cam groove was the equivalent of the peripheral double cam groove used in the Pengeot-Daimler engine of today. Daimler, however, fitted it with a switch actuated by a simple governor, also in the side of the fly-wheel, by means of which the feather running in the grove was shunted so as to run in a nearly circular path, and thus give no motion to the exhaust valve. Thus, when the speed exceeded the normal, the exhaust valve remained closed, no new charge entered, and the speed again falling the governor lifted the switch and allowed the exhaust valve to be opened. The cylinder was cooled by an enclosed fan wheel which sent a current of air around it within a jacket. The crank chamber was practically air tight and acted as a pump chamber with the piston as a plunger.

Daimler, however, was not entirely satisfied with this

motor and kept improving it until he had an engine that was very nearly the equal of the ones in use today.

Carl Benz of Mannheim was about the first to apply the internal combustion motor to automobiles. In 1885 he took out a patent for a tricycle propelled by a gasoline engine. His machine, and the few others that were made about this time attracted very little attention, however, and it was not until about 1894 that the automobile industry began to grow. At this time there were about 100 cars of different kinds in France, and, through the Petit Journal, a race between Paris and Rouen was organized. This race proved a success and gave a great impetus to automobile manufacture. From this time on the French took a leading part in automobile building, and their preliminary work together with the improvements introduced both in France and this country have given us the efficient and facinating automobile of today.

PRESENT STATUS OF AUTOMOBILE INDUSTRY.

The automobile industry, although a comparatively new one, has reached considerable proportions both in France and this country, and it seems destined to be one of the important branches of manufacture in the future.

At the present time, there are about 225 makers of automobiles in quantities in the United States and a number of others which turn out from one to six machines a year. These manufacturers built from fifteen to eighteen thousand machines during 1903 with a value of about fifteen million dollars. Of this amount machines to the value of $1,643,029 were exported during the same time as against $1,069,782 in 1902.

The large strides taken by the automobile industry can be ascribed to three causes.

First, the good times which have given people money to spend.

Second, the immediate acceptance of the automobile by the rich, thus making it a fad.

Third, the presence throughout the country of a large number of bicycle manufacturers with well equipped plants who, because of the lack of demand for that machine, were doing very little business and so were very quick to see the advantage of changing to the manufacture of a machine to which their plants were so well adapted, and for which they could so soon create a demand.

GENERAL CLASSIFICATION AND DISCUSSION OF AUTOMOBILES.

Automobiles may be classified, at present, both as regards motive power, and the service that is to be rendered.

As regards motive power, there are t ree classes; gasoline, steam, and electrically driven vehicles. Of these three, the gasoline machine is at present by far the most popular although there are numerous advocates of the other two types. Its advantages over the other machines are: First, durability, gasoline driven vehicles being lighter than either steam or electric driven vehicles of the same power, have less dead weight to carry and consequently save in wear and tear. Second, economy, the cost of operation being about 1/2 that of electrically and 2/3 that of steam driven machines. Third, ease of operation, and greater mobility, since the gasoline motor, as now manufactured, requires little more attention that one driven by electricity and much less than that driven by steam. A gasoline propelled vehicle also can, without recharging or refilling water tanks, travel three to four times the distance of a steam or electric vehicle.

As regards the steam automobile, its great advantages are:

First, its flexibility and ease of control, it being generally conceded that it is the most flexible and best controlled vehicle manufactured.

Second, the large available supply of energy which

can be called upon for a few moments when a bad piece of road or a steep hill is encountered.

Electricity as a motive power is, of course, out of the question where facilities for recharging the storage batteries are not available, but, in large towns and cities, it is a great advantage because of its simplicity. Practically no mechanical knowledge is necessary in order to run one, it leaves no objectionable trail of odor or steam and is the cleanest of the three types.

Thus it is seen that each type has some things in its favor and, in purchasing an automobile, it is generally a matter of choosing one that will best answer the purpose for which it is intended. It is to be hoped that before long an arrangement will be found which will combine the advantages of all types in one machine.

Considered with regard to the service to be rendered, automobiles can be classed as runabouts, light powered touring cars, heavy powered touring cars, and commercial vehicles. These types of car are built to use any one of three motive powers although very few heavy touring cars are made to use electricity.

Runabouts are made principally for city use being built for good roads and having only from five to eight horse power motors.

The light touring cars are as a rule vehicles with detachable tonneaus, and motors rated at from eight to fifteen horse power. They are generally built for what is

called the middle class trade and are made to sell as cheaply as is possible with good construction. The detachable tonneau is useful in that the vehicle can be changed into a runabout very easily, and, at the same time, the cars are powerful enough to allow for considerable touring.

The heavy powered touring car has probably attracted more attention than any of the other types, not because it is more common, but because of its large power and luxurious appearance. These cars can be obtained with almost any rated horse power from fifteen to fifty, are fitted up in the luxurious fashion that appeals to the richer class, and are capable of making extended tours at a rapid rate of speed.

The last class, that of commercial vehicles, is as yet almost an undeveloped field although great interest is beginning to be manifested in that direction. It is in itself an immense field being even greater than that occupied by the pleasure vehicle, as it varies from the light delivery wagon to the heavy dray and can be put to a much more extensive use than the pleasure vehicle ever will be. In fact, it is thought by many that it is the coming field in automobile industry, and it probably will be if a vehicle can be made that will be as easy to operate and care for as the present commercial vehicles.

RELATIONS BETWEEN WEIGHT, HORSE POWER AND COST:

In order to study the ralations between weight, cost, and horse power of the present day automobile, these items were obtained for a number of the principal American cars and plotted

as shown on pages 15 and 16 . It was, however, found impossible to put any curve through the points determined as they were so greatly scattered. The probable cause of this is the fact that the automobile industry is still in a very unsettled state, no standardization of parts having as yet taken place.

Chart Number 1, shows the cars plotted on a weight-horse power basis, the curve drawn being the locus of points showing 100 pounds per horse power.

Chart Number 2, shows the same cars plotted on a cost-horsepower basis . The curves drawn show the loci of cars costing \$.50, \$1.00 and \$2.00 per pound respectively.

An inspection of the charts will show that the cars that are above the line on Chart Number 1, that is, the cars that have less weight per horse power are as a rule close to the curve showing a cost of \$2.00 per pound. This is probably to be expected as the higher priced materials such as aluminium and nickel steel which are necessary in the construction to give lighter weight per horse power, increase considerably the cost of production.

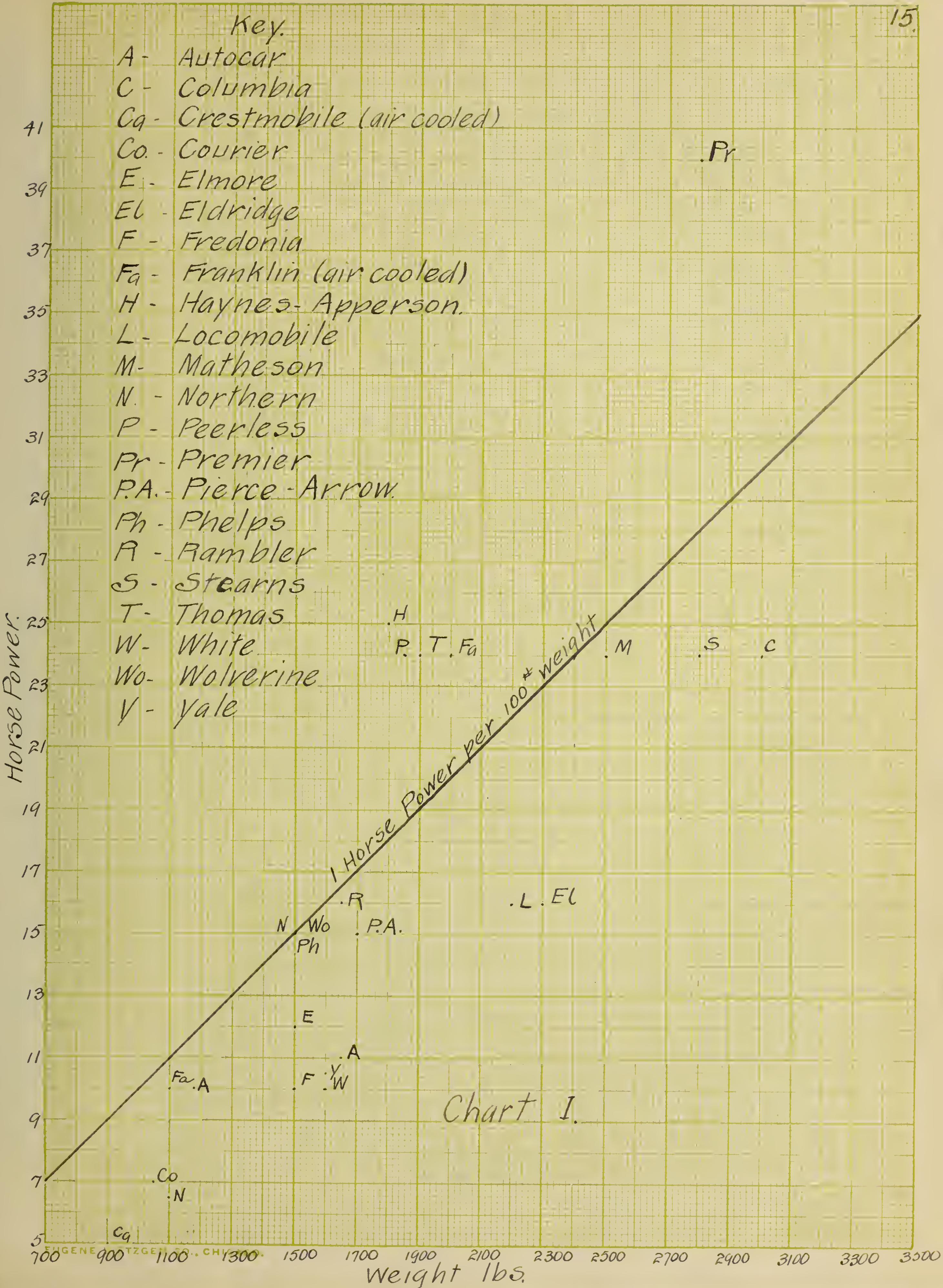
Key.
A - Autocar
C - Columbia
Ca - Crestmobile (air cooled)
Co. - Courier
E. - Elmore
El - Eldridge
F - Fredonia
Fa - Franklin (air cooled)
H - Haynes-Apperson.
L - Locomobile
M - Matheson
N. - Northern
P - Peerless
Pr - Premier
P.A. - Pierce-Arrow.
Ph - Phelps
R - Rambler
S - Stearns
T - Thomas
W - White
Wo - Wolverine
Y - Yale
1 Horse Power per 100# weight
Horse Power
Weight lbs.
41 39 37 35 33 31 29 27 25 23 21 19 17 15 13 11 9 7 5
700 900 1100 1300 1500 1700 1900 2100 2300 2500 2700 2900 3100 3300 3500
Pr H P T Fa M S C R L El N Wo P.A. Ph E A Y F W Fa A Co N Ca

Chart I.

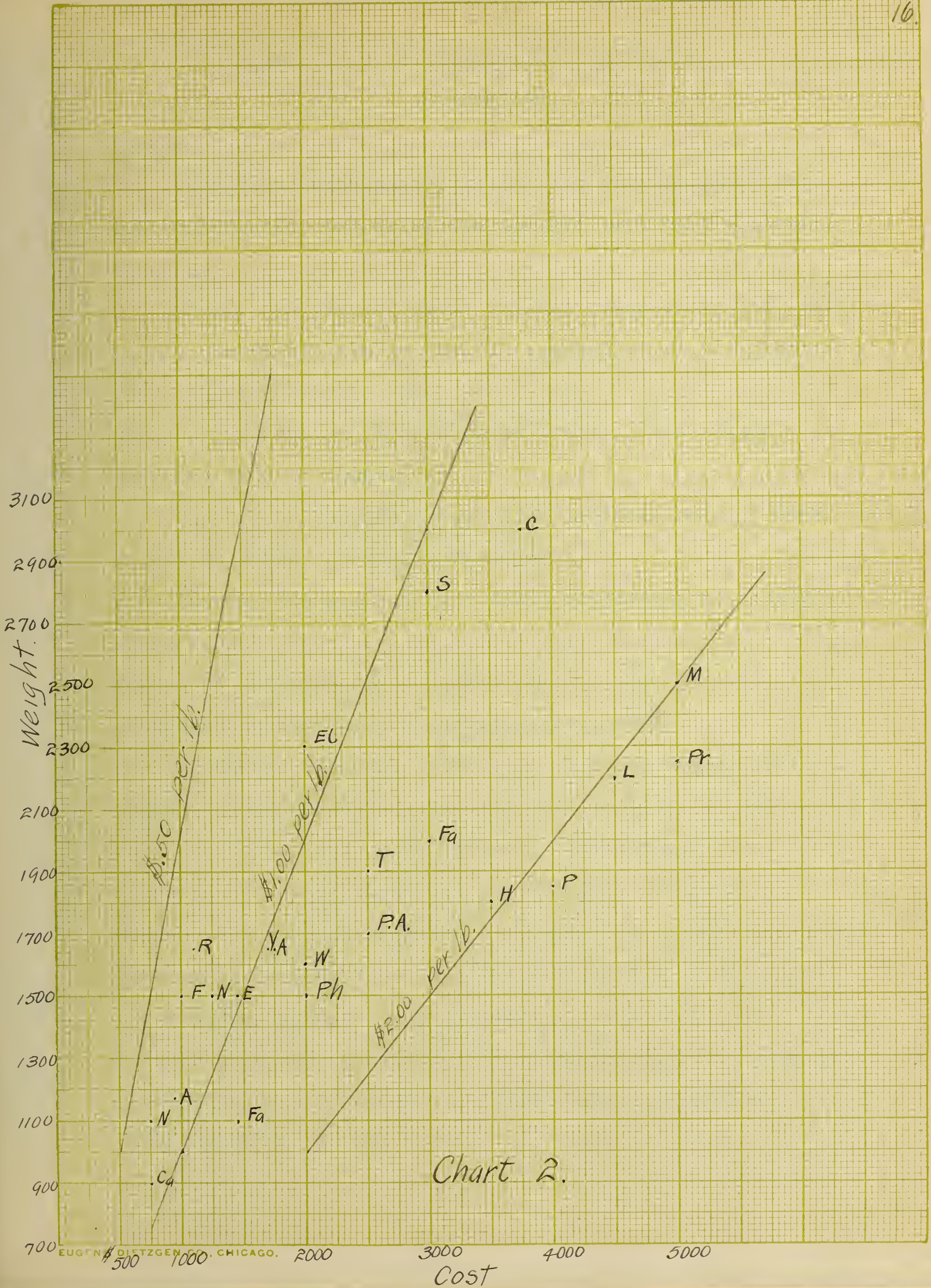
Weight.
3100
2900
2700
2500
2300
2100
1900
1700
1500
1300
1100
900
700
$500
1000
2000
3000
4000
5000
Cost
$.50 per lb.
$1.00 per lb.
$2.00 per lb.
C
S
M
El
Pr
L
Fa
T
H
P
P.A.
R
Y.A
W
F
N
E
Ph
A
N
Fa
Ca

Chart 2.

DETAILS OF CONSTRUCTION OF GASOLINE AUTOMOBILES.

FRAMES.

Considered with regard to the material of which they are constructed, frames may be devided into four general classes:

First, the pressed steel channel frame which has just lately comeinto extensive use in thechasses of the high grade touring cars.

Second, the angle iron frame which is the common construction for runabouts.

Third, the tubular frame which is still used to some extent by makers of high powered cars.

Fourth, the armored wood frame consisting of a main frame of ash interlined with steel flitch plates and reinforced at the corners by forged angle pieces generally elongated to form spring carrying attachments.

Of these different types, the pressed steel frame is coming to be considered the best construction for heavy cars, as it not only gives greater strength per pound of weight, but iscapable of being stamped to any required shape. The general practise at present is to make the members of channel section with the web deepest in the middle and tapering more or less regularly, according to the particular form and arrangement of attached parts, to ward the ends which are stiffened by dropped forged insertions to form the spring horns.

The cross members, likewise of channel steel, and of depth equal to that of the side members where they are attached to them, are squeezed a little at their ends to fit inside the side members and are secured by triangular corner pieces riveted cometimes to both flanges, but more frequently to the upper one alone. These cross members are straight, U shaped, or any other form desired, to suit the motor and change gear box which are usually supported on light pressed channel steel false frames. The thickness of metal used in these frames is generally one-cight of an inch.

For runabouts, the angle iron frame is very good as it can be made plenty strong without excessive weight and the angle being placed thus  the body of the vehicle can be shipped over the vertical part making a convenient method of attaching it.

The tubular and armored wood frames, while still used to some extent are gradually being replaced by those of pressed steel construction, and it is probable that they will be entirely done away with in the near future.

SPRINGS:

When automobiles were first made, the spring construction followed the lines used in ordinary carriage work, but it was soon found that there were several factors entering into the automobile spring problem that did not have to be considered in carriage springs. These were, the necessity of doing away with longitudinal motion because of the

driving mechanisms, the increased speed, and the use of pneumatic tires. On account of these restrictions, the automobile spring must have approximately only vertical motion, must be stronger because of the increased speed, and, on account of the pneumatic tire, it has been found that a softer spring gives much better satisfaction.

The best practise at the present time is to use semi-elliptical springs. In general, the front springs are fastened to the axles by clips and secured to the frame at one end by spring horns and at the other ends by means of links permitting the spring to extend freely. At the rear end of cars with chain drive, two semielliptics are secured to the frame by means of links which permit a free extension of the springs and facilitates chain adjustment. In cars with bevel gear drive, the springs are secured to the frame at one end directly and at the other end by links.

It has been determined by experience, that long springs of moderate flexure and consisting of numerous wide leaves are the best. The flexures generally allowed for passenger automobiles are as follows: For light cars, front springs .4 to .45 inches per hundred pounds, rear springs .45 to .5 inches per hundred pounds. For heavy vehicles, front springs .36 to .4 inches per hundred pounds and rear springs .45 to .48 inches per hundred pounds. The number of leaves should be as great as possible, and silicon or Tungsten steel have been found to be the best material to use in their construction.

CARBURETORS.

These are two general types of carburetor in use at the present time, the float feed or mixer valve, and the positive feed. The float feed is used more at present , not because it is the best, but because it is selfcontained works automatically, and is easily attached to the engine. The principle that they work on is to have the suction stroke of the engine draw a fine jet of gasoline into the mixing chamber where it is met by an incoming blast of air, vaporized, and carried into the cylinder. The result is often an inaccurate charge since the force of suction varies with the speed of the engine, and rich charges are obtained when at a high speed and poor charges when the engine slows down under on overload. These defects, however, have been remedied to a considerable extent the last year or two, and it is now possible to get fairly well regulated float feed carburetors. In spite of these improvements, however, the most progressive manufacturers are discarding this type of carburetor and are making use of positive measures usually of the form of a pump with a variable stroke under the action of the governor. In this way, an exact predetermined amount of gasoline is admitted to the cylinder each time, and, if the engine slows down from excessive loading, the charge will be automatically made richer thus enabling the engine to do the work.

The float feed carburetor shown in Figure 1 is a good example of this class of vaporizer.

This carburetor is placed on the right hand side of the engine and is connected to the intake valves by a copper pipe which contains a butterfly valve for throttling the gas. This pipe leads into a cast iron mixture chamber bolted to the inlet openings. Referring to the figure which shows the carburetor in section, the gasoline enters at F, and flows through the conical valve N, into the float E. The passage K, from the float chamber to the spray nozzle B, is controlled by a point valve A. The air enters at C, lifts the poppet valve D, and passes up through the narrow passage around the opening of the spray nozzle B, creating a suction at this point which results in a jet of gasoline being drawn from the nozzle B, sprayed, vaporized, and mixed with air, and the mixture then flows through the opening G, into the copper pipe before mentioned. A feature of this construction is that there is no fine mechanism connected with the float, the valve N, being an integral part of it. A spring plunger screwed into the opening H, serves as a primer, or a means for flooding the carburetor for starting the engine. The needle valve A, controlling the passage K, from the float chamber to the spray nozzle is surrounded by a strong spiral spring to prevent it from turning out of adjustment. The most original feature of the carburetor is the valve D. As is well known, in all constant level carburetors the mixture tends to weaken as the motor speed decreases as the suction is so weak that little gasoline is sprayed. In this carburetor, the suction must always be sufficient to lift the valveD, no mat-

ter what the speed of the engine may be, and hence sufficient gasoline is drawn in even at very low speeds.

A slight departure from the float feed carburetor is shown in Figure 2. This is a drawing of the Oldsmobile carburetor which, although working on the same general principles as the other does not have the float feed device.

The body of the carburetor consists of a lower part A, and an upper part B, secured together by means of a flanged joint. The air intake is shown at C, near the lower end of A. The air thus enters the carburetor near the bottom, passes upward through the body of the carburetor and leaves for the cylinder at the opening D, in the casting B. A spraying nozzle E, is cast integral with the part A. A slot is planed into the joint surface of the casting B, to receive the plate F, which acts as a sliding throttle valve. This plate is shown separately in the drawing, and it will be seen that is provided with a circular opening, seven eights inches in diameter, and a narrow slot extending from the opening in the direction of the plate. The plate is arranged so that its lower face is just on a level with the upper edge of the spraying nozzle.

Into a lug on the plate F, outside of the valve body is secured a steel rod G, bent in angle form, the lower arm passing through the walls of the casting B. The outer end of this arm is surrounded by a coiled spring H, which nomally holds the sliding plate F,(throttle) in such a position that the passage between the upper and lower com-

partments of the carburetor is nearly closed, the opening being reduced to such an extent that just enough mixture passes to enable the motor to run without load. The rod G is connected by a wire I, to a peddle projecting in front of the driver from the footboard, and by depressing this peddle, the driver can open the throttle and thereby speed up the engine to any desired extent.

The spraying nozzle E, is normally closed by the needle valve K. The stem of this valve is provided with a circular flange a short distance above the throttle plate and the current of air during the suction stroke of the engine acts upon this flange and lifts the needle valve K. The amount of lift of this needle valve is limited by a stop screw L, which is set once for all by the manufacturers, and needs no attention from the user. The upper ends of the needle valve K, and the screw L, are inclosed in a cap M.

Inside the side wall of the casing A, is screwed a casting N, through which the gasoline is fed into the carburetor. The gasoline arrives from the tank at O, and the feed is controlled by the needle valve P. At the bottom of this casting N, is secured a well R, into which any solid matter that may be contained in the gasoline is intended to settle. The well is in the form of a hollow plug and may readily be unscrewed and cleaned out.

Provisions are made for enabling the operator to increase the suction around the spray nozzle, and consequently the spraying or pulverizing action. These means consist of

a collar S, around the nozzle E, through which a number of holes are drilled at a slight angle with the verticle so as to direct any air jets passing up through these holes directly against the jet of gasoline. Normally, the collar rests in its lowest position, as shown being held there by the coiled spring T. By means of the lever U, the operator, by pulling on the outer end of the spring V, may, however, raise the collar S, to the top level of the nozzle E, when nearly all the air is forced to pass through the holes in the collar thus insuring very thorough spraying of the charge of gasoline. This arrangement is useful in starting the engine, particularly in cold weather.

ENGINES.

POSITION: The large majority of the engines in use at the present time are of the four cycle, Otto type placed either horizontally or vertically. One or two foreign cars make use of an engine with a single cylinder and two pistons but this has not proved very popular.

Almost all of the foreign cars use the vertical engine placed under a bonnet on the front of the car, and they are also used considerably in this country on the more expensive cars. Their advantages are better accessability and adaptation to the usual method of driving.

The horizontal engine is used a great deal in this country, especially in the lower powered cars like the runabouts. The advantages claimed are, less vibration, lower center of gravity, more room for a longer stroke and easier lubrication.

As for the one cylinder two piston type, it is claimed that this engine runs much smoother than the ordinary type but on the other had, it is more complicated and probably not so economical.

The number of cylinders used on the cars depends, of course, on the amount of space at hand and the power required. Most of the heavy touring cars are, at present, built with four cylinders and a very few with three. A number of the lower priced large cars are built with two cylinders and nearly all of the runabouts with one.

It seems to be almost universal practise to keep the cylinders small and increase the number to increase the power. By doing this, the torque of the engine is made more constant and weight is saved in the fly-wheel but, at the same time, the number of parts is greatly increased and the mechanism often becomes very complicated. Multiple cylinder engines also cost more to make use more fuel and lubricating oil and require more attention and repairs than would a single cylinder engine of the same power.

CONSTRUCTION. The general method of building the automobile engine at present is to use cast-iron cylinders and pistons, forged steel crank shafts, and the other parts mainly of machine steel. The most difficult part to construct is the cylinder on account of the necessity of coring out the spaces in which the cooling water is to circulate. Because of the unequal thicknesses of the walls, and the lugs, projections, and different passages, the casting is subject to considerable in-

ternal stress because of unequal expansion and contraction, and it is for this reason that objection is made to casting the water jacket as a part of the cylinder.

It has been suggested that a better plan would be to cast the cy linder separately, and then surround the part to be jacketed with a thin corrugated sheet metal jacket. This would simplify the casting of the cylinder a great deal while, at the same time, the removal of the heat from the water would be helped by the radiation from the jacket.

Another plan that has been suggested in regard to cylinder construction is to use steel tubes as cylinders either forming them in one piece or screwing a cap on one end for a cylinder head. By the use of steel, the thickness of the cylinder walls could be greatly reduced thereby helping radiation and decreasing the weight. This plan, however, has the disadvantage of increasing the cost and therefore will not meet with the approval of many manufacturers.

Air cooled automobile engines also deserve mention in connection with the latest practice as, at present, there are a number of cars fitted with engines of this type which are operating successfully. The cylinder of the air cooled engine is made with a large number of ribs on the outside or else it is covered with numerous projecting pins. A constant circulation of air is kept up by a fan driven by the engine, and the large radiating surface provided by the ribs or pins keeps the cylinder cool. In this way the radiator, piping, and circulating pump which are necessary with a water cooled engine are all dispensed with thus simplifying the mechanism and reducing the

weight. While this method has proved successful in light powered cars it is, however, very doubtful if it will be as good in the heavier powered vehicles. On the face of it, it looks almost impossible to circulate enough air around the engine to take care of all the excess heat from a four cylinder, twenty five horse power gasoline motor, but, if it can be done, it will not be long before a large number of manufacturers will chan change from the water to the air cooled cooled engines.

This, however, is not the only place where there is room for improvement. If an engine could be made to run with gasoline andbe controlled with a throttle like a steam engine, thus doing away with the inefficient transmission gears at present in use, the great objection to the gasoline automobile would be overcome.

As built at present, the gasoline automobile engines, especially those used in the cheaper vehicl es, have two common faults viz., lack of compression and defective valves.

The presence of the former defect is generally due to mechanical defects such as ill fitting pistons and valves. In regard to the advantage of high compression C. C. Longridge says in the Proceedings if the Institute of Mechanical Engineers 1902 number 4.

"The principle (high compression) which so greatly advanced the economy of gas engines has scarcely yet been applied to gasoline motors. Reduction in fuel consumption is the great advantage of increased compression or, to state it otherwise,

in any given mixture the explosion pressure produced by ignition is proportional to the charge compression. In practise there are, of course, limits to the degree to which the charge can be successfully compressed. These limits are fixed mainly by four conditions: first the difficulty of keeping pistons and valves tight, second, the necessity of seeing that the negative work and the increased friction due to high compression do not exceed the greater efficiency obtained (the ratio of increase in efficiency decreasing as the pressure increases); third, the desirability of avoiding the excessive shock of a rich charge fired under high compression, and fourth, the risk of premature ignition in a highly compressed charge. It may be useful to consider how far these facts effect present practice as regards compression. A very considerable advance on prevailing compressions will have to be made before the first two causes of limitation come into play. The influence of the third factor, namely the automobile requirements of an easy running engine is already at work, but the complete and satisfactory fulfilment of this requirement is not incompatible with the use of higher compressions than are now in use. All that is required is to reduce the richness of the charge by using less gasoline until the violence of the explosion is sufficiently reduced, the result being an easy running motor, working under the conditions of maximun economy namely, high compression and less loss of heat owing to the lower combustion in the chamber. Poor charges, it is true, lead to increase in cylinder dimensions, but to obviate increased weight we may yet

have recourse to steel cylinders and light water jackets. The third consideration, namely danger of premature ignition, is also a matter of present moment. Two ways of surmounting this obstacle to high compression may be suggested. The first is, as in the Diesel engine, to admit the petrol at the end of the compression stroke. The second method suggested many years ago is a system of internal cooling by water injection."

VALVES. The almost universal practice at present in the matter of valves is to use lift valves with conical seats. Nearly all exhaust valves are mechanically operated by means of cams, but most of the inlet valves are of the automatic type. At present, there is considerable discussion in regard to mechanical operated intake valves. A number of makers have adopted these and claim that by using them it is possible to give the valve a little lead so that it will open before the end of the stroke and thus allow any of the burnt charge that might be left in the cylinder because of back pressure caused by the muffler, to escape before the fresh charge is drawn in. Again at the end of the suction charge, the automatic valve closes while there is still a slight vacum in the cylinder. By operating the valve mechanically it can be kept open a trifle longer, and thus admit a little more of the charge, improving compression and increasing the power.

On the other hand, it is claimed by the advocates of the automatic valve that, while a mechanically operated valve will give more power by admitting more charge, it does not increase economy, but, in fact, decreases it as a great deal more energy is thrown away into the muffler because of the increased exhaust pressure.

In order to take care of this exhaust, the muffler must be increased in size and the weight that might be saved in the engine is counteracted by the additional weight of the muffler. It is impossible at present to decide which of these opinions is right as the only way to judge the two types of valve properly is to give each a thorough trial. The fact that a few of the leading manufacturers have adopted the mechanically operated inlet valve, while it is something in its favor, is not conclusive evidence of its merits, as manufacturers are always looking for new ideas to use so as to make their machine look different and more improved than others, in other words to give them something to talk about.

The incorrect working of the present valves is often caused especially in engines that have been used some time, by the incorrect placing of the exhaust valve. Figure 3 shows the usual method of placing the valves in a gasoline automobile engine. This is faulty because the hot gas will naturally pass through the valve on the side nearest the cylinder, that being the most direct path. By so doing, it naturally tends to throw the valve and seat more on the one side. This, in time, will cause leakage and springing of the valve. A better arrangement is to change the course of the gases before they strike the valve as shown in Figure 4.

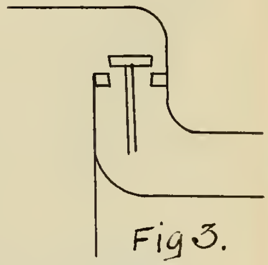
Fig 3.

As regards the proper area for the valve, the information to be had is rather meager. J. J. Roots gives the following formulae

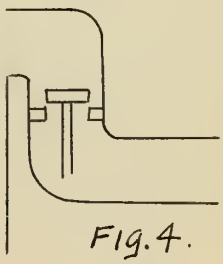
Fig.4.

A area cylinder in inches.

S stroke in inches.

R R. P. M.

e area of exhaust valve, inches.

a area of inlet valve when automatically opened.

m area of inlet valve when mechanically opened.

$$e = \frac{AxSxR.}{21360} \qquad a = e \times 1.18. \qquad m = e \times .75.$$

d outside diameter of exhaust valve.

l lift of exhaust valve.

d outside diameter of inlet valve when mechanically opened.

$$l = \frac{d}{4.1} \qquad l = \frac{d}{4.8}$$

The formulae are for engines up to twelve inches diameter and twenty inches stroke. The area of the valve for each formula is the area taken from the maximum diameter or on the outside of the seating, the width of the seating being taken as 1/9 the outside diameter in the larger engines, and relatively greater in the smaller and higher speed motors. The ports should have not less than 1/4 greater area than the outside diameter of the valve seat.

IGNITION. There are two general methods of igniting the charge in the automobile engine and, as in the case of the inlet valves, there are a number of advocates of each type. The following discussion by Chas. E. Duryea of the advantages of each although a little predjudiced is still pretty thorough and complete.

"How to ignite the charge is unquestionably the most important problem connected with the automobile motor. Some constructors have maintained very rightly that two different elements, such as gas and electricity, should not be introduced in the same machine if it can be avoided, but the advantages of electric ignition over hot tube or slide valve ignition as is frequently used on stationary engines, have made the use of the electric method supersede the other forms. Whether future engines will succeed in eliminating electricity and getting back to the theoretical single system remains to be seen. In the meantime, two general systems of electric ignition are in use, and these receive their electricity from a half dozen sources of current, such as wet coils, dry cells, storage cells, magnetos, dynamos, and oscillating or other brushless mechanical generators.

To begin with the simplest system, the make and break primary current method, it consists of some means for interrupting, inside the cylinder of the engine, an electric circuit from any source of current, which interruption produces a spark that ignites the explosive charge. Four to eight cells, either wet or dry, or two cells of storage battery, with a plain gas lighting coil connected to the make and break device, comprise this system. One wire of the circuit must be connected to an insulated part of the make and break device, while the other is grounded to the engine, of which the moving pieces of the make and break device are a part. Low voltages are used, so that little insulation is required, and ordinary red fibre

or mica, if the parts get hot , suffices nicely. Such simple insulation will not break easily, is very cheap, may be readily renewed (for mica can be obtained at any stove store), and there is little trouble likely to arise from leakage at unexpected places and times. The voltage is so low that water will scarcely carry the current, so it is particularly adapted to wet weather or use in launches. The make and break parts are but little more complicated than similar parts in the jump-spark system, and their only objection is that they are inside the cylinder, and therefore more or less inaccessable instead of outside, as in the other system. Accessability, however, is almost wholly a matter of engine design and this objection is, therefore, one of design rather than one of principle. The moving part must have a joint through the cylinder wall, which must be kept tight by grinding, but the opening is small and good designing removes trouble from this source. This system is so reliable and satisfactory that practically all stationary gas engines in this country use it, and it works equally well with any of the sources of current, or even if connected with an electric light circuit, in which case it is common to keep an electric light bulb in the same circuit, to not interfere with the lighting system.

The secondary or jump-spark method, is the oldest of the two, having been used on gas engines fully forty years ago, It originated in France, and was brought to perfection there on small high speed motors, on which it is believed by many that

the primary system would not give satisfaction because not fast enough. This belief is whollyan error, for the same current that will charge a jump spark coil will produce a primary spark. The error arose from the fact that jump spark coils seldom use magnetic cores longer that six inches, whereas primary coils are usually built longer than this, and in many cases as long as ten or twelve inches. The longer core requirs longer time properly to saturate, but gives in return a longer and better spark, so that the ignition with primary spark is a more satisfactory one because of the better size of the spark, and because most primary coils are long ones, and do not saturate quickly. This impression that the primary system is not adapted to high speed motors has become quite generally accepted. It is also believed that the mechanical parts cannot operateso rapidly with the primary system as with the jump, but this too, is a matter of satisfactory design. Further, it is argued that with the jump coil a vibrator may be used which prevents a continuous contact of preceptible length, and thus prevents running down of the batteries, whereas the primary method makes one continuous contact during a fixed portion of the engine revolutions, so that at slow speeds the contact is long and therefore wasteful of current, while at high speeds the contact is too short properly to charge up the coil. This, too, is a matter of proper mechanical design, and magnetic spark plugs, operated by primary carrent instead of by mechanical means, are now on the market which need use no more current than a jump spark coil, vibrating at the same rate of speed. It is a well

known fact that all transformers lose electric energy in the transformation, and the jump-spark coil is a transformer of low efficiency, so that it is a physical impossibility to get the same electric energy out of the jump spark that can be had with suitable appliances out of the make and break. The principal objection to the make and break to day is, therefore, that it has not been developed for use on high speed motors to the same efficiency as has the jump spark system, but it is being used on a few makes of vehicles at speeds as high as 1200 to 1500 revolutions per minute, amply high for the automobile motor that is to give continuous satisfactory service, which fact proves its thorough adaptability and since it is simpler that the double circuit, high voltage jump spark system, has a large future ahead of it. Such prominent foreign concerns as the Mors and Mercedes vehicles are using primary systems, the electricity being furnished by magnetos driven by the motor, and a system used by such reputable concerns meeds no excuses. In America, the long established Duryea and Haynes-Apperson systems use the primary method although they also furnish the jump-spark ignition, while the Phelps, which has made such an excellent showing on hill work, is also of the make and break variety.

The jump-spark coil consists ordinarily of a primary coil of two layers of 20 gauge wire around a soft iron core, about 6 inches long by 3/4 inches in diameter. For a make and break spark more of this wire would be used, thus lessening the amount of current that can flow through it during any given a-

mount of time, so that by comparing the two windings, it would seem evident that the jump-spark system must require more current than the primary. As a matter of fact, it requires a greater amperage or quantity, although the winding of the coil permits a lower pressure or voltage to be used. Because of this difference a battery or a magneto that gives satisfaction with one system may not be saitsfactory with the other, and on this account observors are frequently misled because they fail to get results from a given source of electric current with one system whereas they get good results from the same source with the other system. Around this same core, having two layers of No. 20 primary wire, is placed a mile of No. 36 wire, forming the secondary circuit, and the passage of a current through the primary induces a current in the secondary wire, which, because of the large number of turns is of very high voltage- so high that it will jump an air gap of 3/8 to 3/4 of an inch. The ends of this secondary wire are brought near each other inside the firing chamber and when the current is connected or broken in the primary circuit a spark jumps the gap between the ends inside the firing chamber. Because of certain properties not necessary to explain here, this spark is usually seen only when the circuit is broken. For the purpose of passing this current through the cylinder walls without loss, spark plugs, usually of porcelain having very high insulating qualities, are used, and a great variety of these are on the market, each claiming advantages over the other; proof ample of the difficulties of handling such high-tension sparks. Not only must the coil be made with the greatest care and the best of insulation, and

therefore at higher cost, but the conducting wires must be heavily insulated with rubber, kept free from water and the plug must be kept free from soot or burned oil, for anything like a conductor is liable to lead away the current. The application of one's perspiring fingers to the outside of the plug will sometimes leave a trace of salt sufficient to afford a path for the spark, and thus cause inexplainable misfires. Compressed air is not a good conductor, so the spark jumps with difficulty in higher compressions, although the heat of the gas, due to compression, is such that very little spark is necessary to ignite it. A make and break device must be provided somewhere on the engine to properly connect and disconnect the primary circuit, and this performs the same function as the make and break device inside the cylinder of the primary circuit engine. Some users claim to have secured much better results from one system than from the other, but the fact that 26 per cent of the stops in the run from New York to Boston and return were caused by ignition troubles, and that all the vehicles entered, with but two or three exceptions, used the jump-spark system, indicates that this system is far from perfect, and it is the writers belief that effort should be expended on the developing of the primary system, which promises the best future results rather than on the secondary one.

As to the sources of current: The wet galvanic cell is ordinarily used for stationary engines, and thus was first applied to automobiles. The tendency to splash and the nastiness of creeping solutions, very active chemically, brought wet cells into disfavor, to be replaced by cells that contained only a

loose paste and were sealed so that under ordinary conditions no liquid could escape, commonly termed dry cells. The energy contained in these, however, is so much less that they are very unreliable sources of current. The most active wet cells are those using alkaline solutions with copper anc zinc as the elements, but caustic soda or potash is so corrosive that it is unpleasant to handle or attempt to carry such cells. Another good, though less active wet cell uses carbon and zinc, elements with a sal-ammoniac solution which is both less active and less destructive to fingers and clothing. The dry cell is of this order, but more limited in action. A cell recently brought out uses lead and zinc as the elements and seems to give a straight line discharge, i. e., the discharge is continuous in amount from the beginning until the cell is completely exhausted when it drops very rapidly. This cell, if it proves to be as promised, offers much hope to those who use batteries as a source of current. In 1896, the makers of the Duryea vehicles had constructed on a special order small self-acting dynamos, weighing about twenty pounds, carefully built at considerable cost, which would give more current that the ordinary set of batteries and could be driven by a belt from the fly-wheel of the motor. Some of these would start so promptly that no batteries were needed for ignition purposes and they behaved very nicely. Governors were applied to prevent over-speeding, for, being self exciting, these dynamos had to run at fairly constant speeds. A little later a Western stationary engine concern equipped their engines with alternating carrent magnetos

geared so that the maximum strength of current came at the circuit breaking moment. Since this time, the use of magnetos and dynamos for generating current for automobiles has become quite common, the dynamo being used for jump-spark work because of the large amperage required, and the magneto for make and break. The dynamo, however, is not only heavier and more expensive but requires more power to drive, which is very conclusive evidence that the jump-spark system for equal results must have more current. The dynamo requires such an amount of power that on turning an engine rapidly with compression relieved the pull of the dynamo is felt very perceptibly by the operator, whereas, with the magneto the pull is not noticeable under the same conditions. Since the direct current generator is more complicated than the alternating one, there is a tendency to favor alternating or oscillating magnetos, and the alternating magneto geared to the motor is used by the Mors and Mercedes in connection with the make and break devices in the cylinders, while the oscillating is being used by stationary engine people with great success. Quite recently modifiers of the oscillator have been advertized in the automobile magazines, and experiments are being made with this in connection with magnetic spark plugs, which may be interchanged the same as jump-spark plugs are now. One form of generator has neither brushes nor armature; the fly-wheel of the motor taking the place of these parts, so that it has no bearings, and needs no attention whatever after once being put in position. Certainly a device of this kind surpasses anything heretofore offered in the matter

of simplicity, reliability, and durability. Whether it is advisable to use magnetic spark plugs or whether mechanical devices, as are used from one year's end to the other on stationary engines will be found most reliable is a question; but it is probable that a system that works so well on stationary engines could be easily used to advantage on automobiles.

The size of the spark is another phase of the subject of ignition which is of more importance than many realize. Many drivers know the difference in vim shown by their motor after they have fitted a new set of batteries, but do not realize that this difference is due to the size of the spark, and think that as long as they are getting sparks regularly they are getting all that can be required, whereas this is far from being true. On this account a mechanical generator that insures a big, thick spark every time is far superior to batteries for ignition purposes, and the motor is not only rendered more efficient but more economical, if given a strong source of current. It is well known that any source of light looks larger than it really is, and a jump-spark is probably as deceptive an affair as can be imagined. If a piece of paper be drawn between the points of a spark plug in operation a number of minute holes will usually be burned through it. If the spark is strong, these holes are of visible size, but if the spark is weak the holes will be so small that even when the paper is held to the light they cannot be seen. This method of getting at the diameter of the spark is probably as accurate as any convienient method.

Suppose for sake of argument, this spark, instead of being the size of the point of a needle or smaller, was as large as the head of a match, it is quite evident that its ability to ignite a charge would be many times increased, probably as the cubes of their comparative diameters so that, with a large spark, the ignition is practically instantaneous, whereas with a small spark the ignition must be advanced far ahead of center in order that the charge may be fully ignited in time to do its work. It is well known that certain explosives burn harmlessly if simply ignited but if detonated by suitable percussion cap or other method, they explode with great violence, and it has been maintained by some gas engine experts that this is what happens in a gas engine if given suitable spark. A small spark does not produce the instaneous explosion or detonating effect, whereas the large spark does, with the result that there is a decided difference in the power of the motor. This is one reason why the primary spark is preferred by some instead of the jump for the large spark produced by the primary method not only makes better ignition, but it will ignite a less homogeneous mixture, thus permitting a wider range in the mixing of the fuel and adding to the economy of the motor. Some have argued that a jump-spark will set fire to a piece of paper, whereas the make and break will not, but the comparison is not a fair one, for it is impossible to produce the make and break spark with the paper between the metal points, and impossible to introduce the paper after the spark is made, in time to receive its effect. Further the paper in one instance

can only be exposed to a single spark, whereas in the other instance a stream of sparks is made. The behavior of gases, however, is different from that of paper, for the metallic points cannot be separated without causing the gas to flow between them and thus have the same opportunity to ignite as with the jump-spark, the only difference being that when the metalic points of the make and break system are cold they tend to cool the gases and thus may interfere with steady ignition. This disappears, however, as soon as the engine warms up and does not interfere with the regular service."

GOVERNING. There are three different methods used in regulating the speed of the automobile engine, and all three of these are generally used on every car.

The governor proper, that is the mechanism which prevents the engine from racing, is generally of the centrifugal type and acts by preventing either the exhaust or the inlet valve from opening. On most of the foreign cars, the former method is used that is, two rapidly revolving weights spread out far enough, when the engine is running above speed, to act on the exhaust valve through a system of levers, causing it to remain closed. In this way, the cylinder is left full of the exhaust gases and no new charge is drawn in. The other method which is used considerably in this country has the same centrifugal weight arrangement but when the weights open out the exhaust valve is not interfered with, but, instead, the inlet valve is prevented from opening and so no new charge is taken into the cylinder.

The question as to which of the two methods is the better is a hard one to decide as there is very little choice between them both accomplishing the regulation by practically the same means. There seems, however, to be one or two small points in favor of the inlet valve regulating type. In the first place, the hot exhaust gases, being left in the cylinder, will be compressed again and therefore reheated to a pretty high temperature. Some of this heat will go to heating up the cooling water in the jacket, and thus the radiator will have more heat to dispose of and, as the time when the engine is most likely to race is when running light, that is when the car is running slow or stopped, the added heat will come at a time when the radiator is less able to dispose of it on account of the small current of air. Also, all the heat taken out in this way represents so much lost work. With the other method, there is no gas left in the cylinder to be compressed, and therefore the circulating water has no extra heat to dissapate. Again, it is probably somewhat easier to design a governor to act on the automatic inlet valve which is generally used than it is one to act on a mechanically operated exhaust valve.

The other methods of governing the engine, instead of being automatic in action like the one just described, are generally controlled by the driver of the automobile.

One of these devices, commonly called the throttle, regulates the speed of the engine by throttling the charge, that is by allowing a less supply of gasoline vapor to be drawn into the cylinder with the usual amount of air or in other words by

decreasing the richness of the charge. In this way, the resulting explosion pressure in the cylinder is less and less power is developed by the engine.

The third method of engine regulation is by means of the spark. In order always to get the highest power out of the engine for a given charge, the igniting spark should pass in the cylinder just as the engine crank passes the inner dead point. If it comes later than this, the piston will have travelled over part of its stroke before any of the live pressure will have been created, and so some of the power will be lost, while, if the spark passes earlier, the ignition pressure will act on the piston before it reaches the dead point and thus cause heavy strains in the engine.

The time of spark is regulated by cams on the engine shaft and is fixed to occur at a certain point in the stroke and thus it seems as if the spark could be set right once for all. There is one thing yet to be considered, however, and that is the fact that it takes a certain time to get a spark in the cylinder after the current is broken by the engine. Because of this fact, it has been found that when the engine is running at medium and high speeds, the spark regulator has to be set ahead so that the current will be broken a little before the engine reaches the dead point as the piston moving very rapidly (often 1500 to 2000 feet per minute) will reach the end of the stroke before the spark takes place. From these facts, it can be seen that the proper time of sparking influences the speed of engine materially and must always be considered.

The general practice, as has been said, is to place both the throttle and the spark advancer separately under the control of the driver but there are a few exceptions to this. One or two makers, for the sake of simplicity, have so arranged these two controls that they will both work by moving one lever, that is by opening the throttle the spark will be advanced. This is not good engineering as it often happens that a heavy grade or bad road will be encountered which will require the full power of the engine at a slow speed, that is the throttle will have to be wide open and the spark very little advanced. With the arrangement under discussion, this is impossible and the spark is very liable to pass before the piston reaches the dead point which is very harmful.

Another arrangement is an automatic spark regulator which, by means of a centrifugal governor, regulates the time of spark making it earlier the faster the speed. This is an excellent arrangement being an improvement on the hand control as many drivers resort to the spark advancer for almost all speed regulation. This is very uneconomical as, for each speed, there is only one correct position for the spark. If it is delayed until later than this, the speed of course will be decreased but at the expense of fuel that is thrown away. For this reason any automatic spark regulator is an excellent thing as regards economy of operation.

COMPOUNDING. One of the late developments in the automobile engine field is the compound gasoline engine. An engine of this type was introduced this year (1904) by Eisenmuth

Horseless Vehicle Company of America and is claimed by them to be a great advance in gasoline engine design. The engine consists of two ordinary four cycle cylinders which, instead of exhausting into the muffler, exhaust into the low pressure cylinder. The two direct acting engines operate alternately so that the low pressure cylinder receives an impulse every recolution. This design, while it is claimed by the company to be as great an advance in its field as were compound steam engines over single cylinder ones, does not seem to be anything extraordinary, and it is to be questioned if it would not be better to lengthen the stroke of the direct acting cylinders sufficiently to give the desired expansion instead of bothering with the extra cylinder. Its advantages certainly do not compare with those obtained by using compound steam engines as there is no cylinder condensation to be avoided. About the only advantage it will have is that the torque of the engine will be more even as it transmits the power to three cranks instead of two, but this advantage is not great enough to call for the complication of parts and added weight necessary to the construction.

RADIATORS.

Radiation of the heat taken in by the jacket water of the gasoline engine is accomplished by means of a radiator placed in the forward end of the carriage.

There are two principal types in use, namely the coil radiator consisting of coils of copper pipe generally five-eights of an inch in diameter constructed with fins of either copper or tin placed close together all along the coils, and the honey-comb radiator which is generally a rectangular copper box having tubes running through from side to side something like a multi-tubular boiler.

In order to determine the best materials and methods to use in the construction of these radiators and also to determine their relative efficiency, the Bricoe Manufacturing Company of Detroit which makes a specialty of coolers made a series of tests on those of their own make the results of which follow.

As regards the radiation of the different coil radiators the following results were dirived taking the best one as 100.

Copper tubes 1 3/4" copper fins soldered and coated 100,

Copper tubes 1 3/4" copper fins not soldered but coated 70,

Copper tubes 1 3/4" copper fins not soldered not coated 52,

Copper tubes 1 3/4" tin fins soldered and coated 58.

In regard to coating, it was found that as many as fourteen coats of lamp-black paint or varnish could be applied, and increase the efficiency slightly with each coat. After the fourteenth coat the efficiency slowly decreased. In practice, however, only two coats are used as two stick better than a greater number.

Tests were also made on various types of honeycombcoolers, the results obtained showing an efficiency no greater than the tubular type in proportion to the amount of radiation, that is to the surface exposed to the air provided the tubes were one-half inch or less and so arranged that the area of the water channel resulted in practically the same speed of the water through the cooler. This refers to the drop in temperature, but a further discovery was made that the efficiency of the honeycomb radiator depended largely on the rapid passing of water through it, it having to pass through oftener in a given time than through a tubular radiator in order to abstract the same amount of heat. A honeycomb radiator may give good efficiency for a year or two but a deposit is bound to form in it which decreases its efficiency and results in a rapid deterioration of the cooler itself. Many manufacturers use the honeycomb radiator because it is considered a neater appearing arrangement and so appeals to the purchasing public.

The means imployed at present to circulate the water through the cooling system is almost always a forced system, that is circulating the water by means of a small centrifugal pump driven by the engine. In the four cylinder engine where the heater has to handle considerable hot water it is also usual to put a direct connected fan behind the radiator to assist the circulation of air.

TRANSMISSION GEAR.

The transmission gear of the automobile includes all the mechanisms which transmit the power of the engine to the driving shaft and therefore takes in the clutch, change speed gear, transmission shaft or chain, and differential gear.

The clutches generally used are of the friction type either conical or expanding, the former being the more common. Considerable care has to be taken in their construction as they must be gradual in action, simple, capable of being entirely disengaged instantly, must not slip under normal conditions, and be unaffected by heat, moisture, dust, etc. The clutch generally employed consists of two truncated cones fitting closely into one another, the female cone being formed by the fly-wheel of the engine while the male cone is usually of very light aluminum construction and is movable lengthwise on its shaft. The male cone is always surrounded by leather in order to secure gradual action and prevent sticking. The friction coefficient generally has a value of from .12 to .20 depending on the leather used. The dimensions are calculated as follows:

Let E, represent the effort to be transmitted at the mean circumference; a, the angle of inclination; R the radius at this circumference: P the actual pressure necessary in order to transmit the effort E, and f, the friction coefficient at the friction surfaces of the cones then,

$$P = E\left(\frac{\sin a}{f} + \cos a\right) = \frac{ER}{R}\left(\frac{\sin a}{f} + \cos a\right)$$

ER is the couple which must be transmitted by the shaft.

The angle at the apex of the cone should never be less

than eight degrees to prevent sticking of the clutch. In order to diminish the pressure to be exerted, and consequently the force to be transmitted, the cone is made as large as possible within the motor fly-wheel limits.

The change speed gear which is located in a gear box close to the clutch is an arrangement of gears by means of which the power received from the clutch is transmitted to the driving shaft or chain at different ratios to the engine speed. There have been in all six methods used in the construction of the speed changing mechanism namely, by stepped pulleys and belts by the separate clutch system by the sliding key system, by sliding gears known as the clash system, by a planetary combination and by frictional devices. Of these the most common at present are the clash system and the planetary system although the separate clutches are still used somewhat. Of the first two, the planetary is always used on light cars while the clash system is used on the majority of heavy cars and also on a number of light cars.

The separate clutch system, as the name implies has a separate clutch on each combination of gears used, and the speed ratio desired is obtained by engaging the corresponding clutch. This necessitates that all the gears used be always in mesh whether working or not.

The sliding gear system, on the other hand only has the gears that are transmitting the power at the time in mesh and the speed ratio is changed by sliding the gears along until another ratio is obtained by the meshing of two other gears. With this system, a device is generally provided which prevents

the shifting of the gears until the main clutch is thrown out, thus preventing the stripping of the gears through too sudden meshing, when the power is on.

The planetary system as generally constructed has a main gear on the engine shaft on which roll three or five pinions held in a frame concentric with the shaft and which also mesh with an internal toothed wheel which surrounds the whole combination. The different speeds are obtained by holding one of the parts, preventing it from turning. Thus, if the frame holding the pinions is clamped, the reverse motion is obtained. If the internal toothed gear is clamped, the low speed is obtained from the pinion frame, and if the whole mechanism is made to turn, the high speed is obtained. The disadvantage of this gear is that it only gives two forward speeds and is also liable to become loose and rickety. These are the reasons it is not used on the large cars instead of the clash system, the latter giving as many speeds as dsired when it is constructed and wearing extremely well.

The usual method employed in transmitting the power from the change gear box to the driving axle is by means of sprockets and chain although there are at present a number of good cars on the market equipped with a logitudinal shaft which transmitts the motion. The chains used are stamped from good quality steel and the pins are hardened. A patented chain which permits of the easy addition or removal of links is generally used.

When the shaft drive is employed two universal joints are used one close to each end and the shaft is also built to allow

for some longitudinal play.

The differential gear which is the machanism that receives the power from the chain or shaft, is used to enable one wheel on the driving axle to travel faster than the other as when rounding curves. In its most common form, the driving axle is divided at its center one half of it being fast to each wheel. To the inside end of each axle is fixed a bevel gear, the two gears facing each other in close proximity. Between these two gears is placed a frame carrying a number, generally three, bevel pinions which mesh with both bevel gears. This frame which carries the pinions, carries fast to it externally the sprocket by which the axle is driven or a bevel gear that is actuated from the shaft coming from the speed change gear. The whole arrangement is strongly braced so as to made the devided axle as nearly strong as a solid one as possible. When both driving wheels move at the same speed there is no motion between the pinions and gears but on a curve one bevel gear moves faster than the other thus causing a relative motion between the pinions and gears.

The rear axle which is generally of solid steel inclosed in an outside casing and is provided generally with ball thrust bearings which take up the thrust of the bevel gears in the differential and also with supporting bearings close to the driving wheels.

LUBRICATION.

Engine lubrication in American runabouts is usually performed by a sight feed lubricator supplying oil directly to the piston, or two of them when the opposed cylinder motor is used. Crank pin and main bearing lubrication is by splash from the enclosed crank case in the majority of cases. A multiple force feed lubricator usually takes the place of gravity cups on the multiple cylinder engines of touring cars and may be conveniently located on the dash where it is easily watched.

Transmission gears in both runabouts and touring cars are usually in oil tight cases which enable the gears to operate in a bath of heavy oil, and this is generally true of differentials and bevel gear drives found in high priced cars. Ball and roller bearings in both types of car are generally packed in grease and operate for a long time without attention. Grease cups are employed freely on engine main bearings, the plain bearings of countershafts and all plain journals not otherwise provided for. On the runabouts there are usually quite a number of points requiring oil from a can, but in the higher priced cars a mechanical magazine lubricator piped to these various points delivers the requisite amount of oil at all times when the car is in operation, and automatically cuts off the supply when the engine stops

WHEELS AND TIRES.

The general practise at present in regard to wheels is to use what is called the wood artillery type. They are of rather heavy construction, made of second growth hickory and have a

very strong appearance. In the early days of the automobile there were a large number of steel wire wheels used, probably because of the influence of the bicycle, but it was found that they were not nearly so good as those of wood construction because of their liability to rust and bend especially on the heavier cars. The diameter of the wheels used has been steadily increasing and the thirty two inch wheel is now coming rapidily into use. This change although it increases the tire cost considerably is still a good one because of the easier riding qualities on rough roads. The rims. of the wheels are generally of a patented construction to allow for the easy attachment of the tires.

The tires generally used are pneumatic and detachable as it has been found that for the high speeds and rough roads that is the only practical one as it gives good resiliency and an easy method of repair. On account of the large cost of repairs with the pneumatic tire, number of inventors have been working on the problem of a solid puncture proof tire that will have enough resiliency for the work but as yet there have been no great advances in that line. It has been found that for good roads with large diameter wheels and speeds not to exceed fifteen miles per hour, it is permissable to use solid tires. This means that solid tires can be used only in cities, as, for touring purposes, the roads are too rough and the speeds too high to think of using them and the pneumatic tires have been left in possession of that field.

STEERING GEAR.

The steering of the automobile is accomplished by means of a lever or hand wheel in front of the driver, which extends through the bottom of the body and then by means of a worm or a gear moves a sector of another gear which in turn moves two levers attached to the front wheel axles. The whole front axle of the automobile is never moved in order to turn the car, but instead, the part of the axle that the wheels turn on is pivoted just inside of the wheels to the stationary axle. All that has to be moved, then, to change the direction is these two small axles.

It is necessary, when designing a steering gear, to use a combination of gearing that will absolutely prevent any motion in the reverse direction, that is any tendency of the wheels to move caused by ruts in the road will not be communicated to the steering wheel. Also, on account of the necessity of doing away with all looseness or back lash in the gearing and rods, the gears and worms used are of steel and generally of the very best workmanship. In order to preserve the gears in this good working order, it is necessary to enclose all gears in dust and oil tight cases which are generally partially filled with oil or grease thus reducing the wear to a munimum. On of the latest improvements is to construct the steering column so that it can be moved forward and back without at any time being out of gear. This enables the oper tor to throw it forward against the dash when not in use and also allows him to change its position when on long tours. The hand wheel used is of wood and the steering

post besides transmitting the motion carries the controlling levers such as the spark advancer and throttle.

CONCLUSION.

In conclusion it may be said that although there are a large number of points in gasoline automobile construction that have room for improvement, the importance that these vehicles have attained in the manufacturing field has turned the attention of a large number of inventors towards them, and every month brings out improvements to some part of the machine. It is also probable that before long considerable attention will be paid to the standardization of automobile construction with its accompanying benefits to both manufacturers and users.

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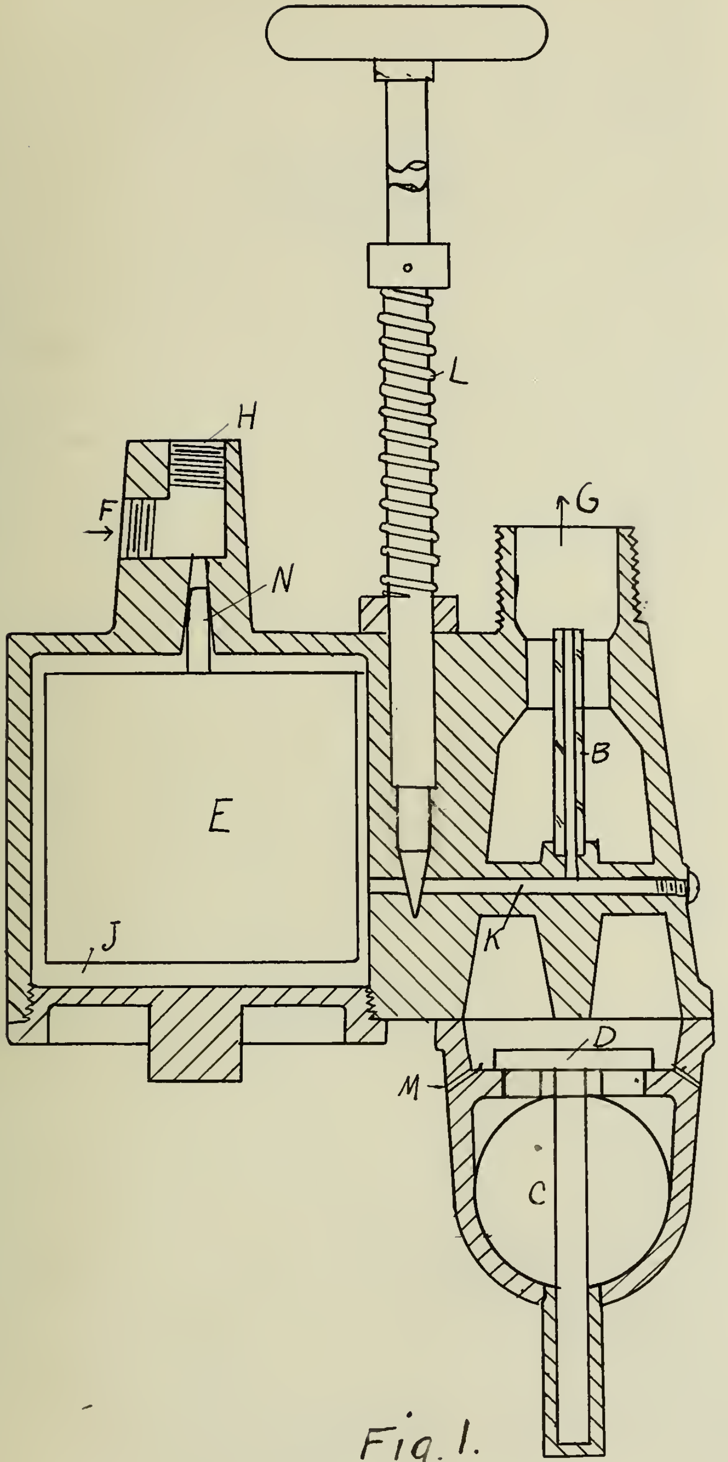

Fig. 1.

Float Feed Carburetor.

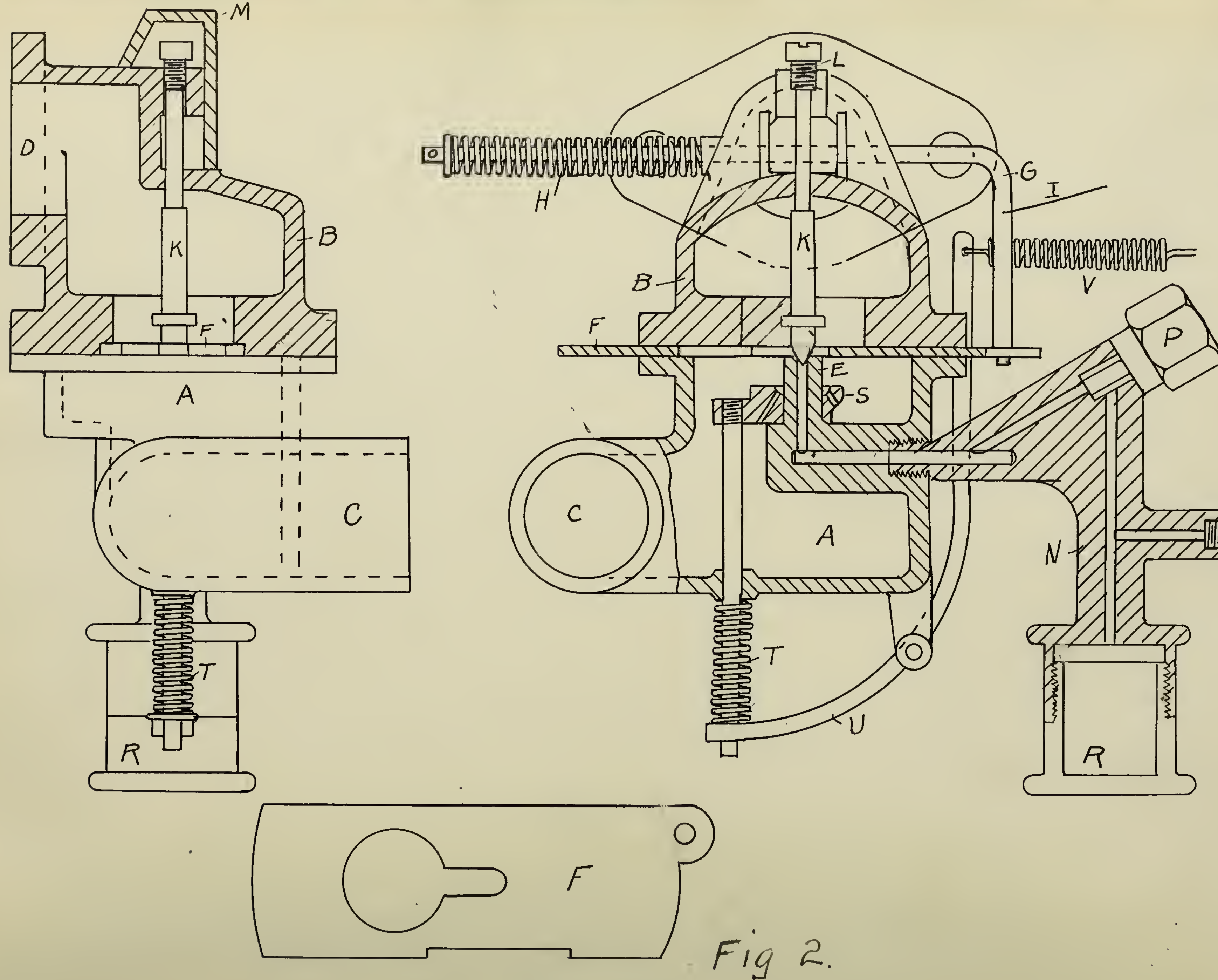

Fig 2.
The Oldsmobile Carburetor.